

Predicting the Evolution of Tidal Channels in Muddy Coastlines

Sergio Fagherazzi

Department of Earth Sciences and Center for Computational Science

Boston University, Boston MA 02215

Phone: (617) 353-2092 Fax: (617)-353-3290 Email: sergio@bu.edu

Award Number: N00014-07-1-0664

LONG-TERM GOALS

- To develop methods to predict the long-term evolution of tidal channels in muddy coastlines as a function of sediment availability, hydrodynamics, and climate change.
- To develop predictive, high-resolution models for the hydrodynamics and sediment dynamics of tidal channels in muddy coastal environments
- To quantify the relationships between sediment supply to tidal channels, resuspension of fine material in the shelf by wind waves, and sediment input from major rivers.

OBJECTIVES

- Measure the supply of sediments to a Louisiana salt marsh and the short-term sediment deposition on the marsh surface.
- Apply, test, and validate a high resolution hydrodynamic-sediment transport model in a Louisiana marsh and determine the short-term evolution of the tidal channels and the erosion deposition patterns on the marsh platform.
- Integrate the short-term results of the high resolution numerical model in already developed long-term models of tidal channel evolution.
- Link the transport of sediments to salt marshes via tidal channels to the resuspension of fine sediments in the adjacent shelf.
- Compare the results of the MURI project “Mechanisms of Fluid Mud Interactions under Waves” to measurements of sediment concentration in a nearby marsh channel.
- Share and merge the model and results with those of the MURI Research Group.

APPROACH

Field Component: We will focus on the Little Constance Bayou, a creek in the Rockefeller State Wildlife Refuge (fig. 1) to characterize the fluxes of sediments from the shelf to the marshes, in this project we propose to measure the sediment concentration and tidal fluxes in one creek of the Louisiana marshes. We will deploy a Nortek ADCP with an Acoustic backscattering System at the

Report Documentation Page				Form Approved OMB No. 0704-0188	
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1. REPORT DATE 2007		2. REPORT TYPE		3. DATES COVERED 00-00-2007 to 00-00-2007	
4. TITLE AND SUBTITLE Predicting the Evolution of Tidal Channels in Muddy Coastlines				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Boston University, Department of Earth Sciences and Center for Computational Science, Boston, MA, 02215				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Same as Report (SAR)	18. NUMBER OF PAGES 5	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

mouth of the creek to measure tidal elevation, water velocity, and concentration of suspended sediment in time. Ten sediment traps (mineral filters mounted on a plastic tile) will be deployed in different marsh locations, encompassing different elevations and distances from the creek. Four channel cross sections will be surveyed at the beginning of the project and monitored in time with erosional pins.

High resolution modeling component: To simulate the marsh hydrodynamics and sediment dynamics we will utilize the Delft3D modeling framework. The model will be set up using the LIDAR topography shown in Fig. 1 The Little Constance Creek represents an ideal site for simulations of marsh hydrodynamics since its watershed is well delineated by ditches that constitute impervious boundaries for tidal fluxes (Fig. 1). Measurements of tidal elevation and sediment concentration at the creek mouth will be used as boundary conditions for the model. The Delft3D model will be run with the data collected by the ADCP during the high resolution measurements conducted in February-March of 2008

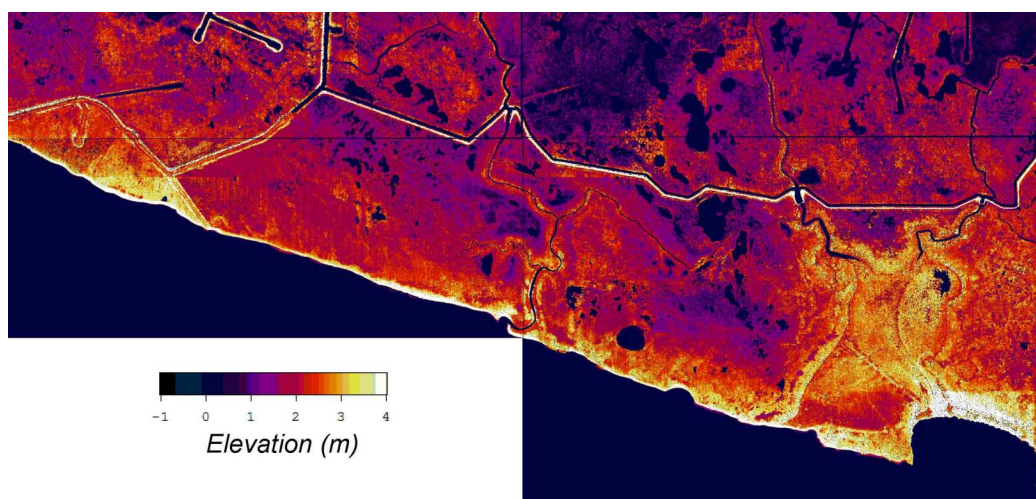


Figure 1: LIDAR altimetry of the study site (1m resolution). The LIDAR altimetry will be used as initial condition for the hydrodynamic model.

Integration of short-term high-resolution models with long-term simplified models:

In recent years we have developed a suite of morphological models that quantify the response of salt marshes to changes in sea level, sediment supply, vegetation, and substrate characteristics. The models are able to simulate the feedbacks between morphology and wave propagation in salt marshes (Fagherazzi et al. 2003, Rinaldo et al. 1999), the long-term variations in channel cross section (Fagherazzi and Furbish 2001, D'Alpaos et al. 2006) The development of the channel network (Fagherazzi and Sun 2004, D'Alpaos et al. 2005), the feedbacks between vegetation and sedimentation (Mudd et al. 2004) and the repartition of intertidal areas between tidal flats and salt marshes (Fagherazzi et al. 2006a; Fagherazzi et al. 2006b).

All these models rely on simplified, physically based hypotheses for tidal flow and sediment transport. Our long-term plan is the integration of short-term and long-term models in the same framework.

WORK COMPLETED

In order to integrate field measurements with long-term evolution models we have developed a geomorphological theory of tidal basin response to describe specific characteristics of tidal channel hydrodynamics. From point measurements of velocity and sediment concentration at the channel outlet we can have a first estimate of the morphological characteristics of the muddy coastline. Vice versa, the morphology of the intertidal area can provide us a first estimate of tidal fluxes in the channels that can be used in long term morphodynamic models of marsh evolution.

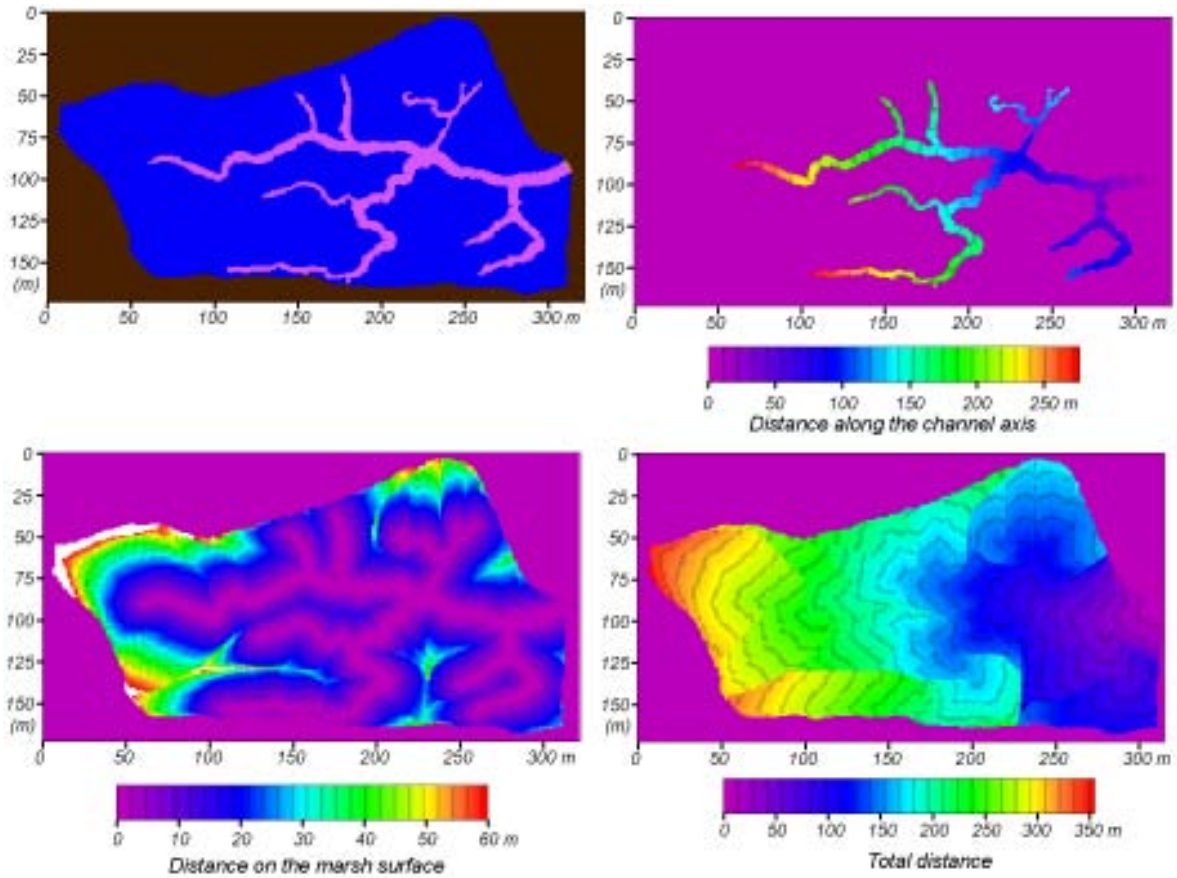


Figure 2. Calculation of the hydraulic distances (from the outlet/inlet) in a marsh watershed. a) salt marsh watershed and channel network extracted from aerial images; b) distances along the channel network; c) distances on the marsh surface; d) total distance (sum of the distance along the tidal channel and the distance on the marsh platform) for every marsh location. The creek under analysis is located in Warham, UK.

RESULTS

Our modeling framework explains the asymmetry in the stage-velocity relation in muddy tidal channels and the existence of velocity surges as an effect of the delay in the propagation of the tidal signal within the marsh area (Fig. 3). The travel time distribution and the hydrodynamics of tidal watersheds are thus related to the geomorphic structure of the salt marsh and, specifically, to the distance traveled by water particles within the channel network and on the marsh surface.

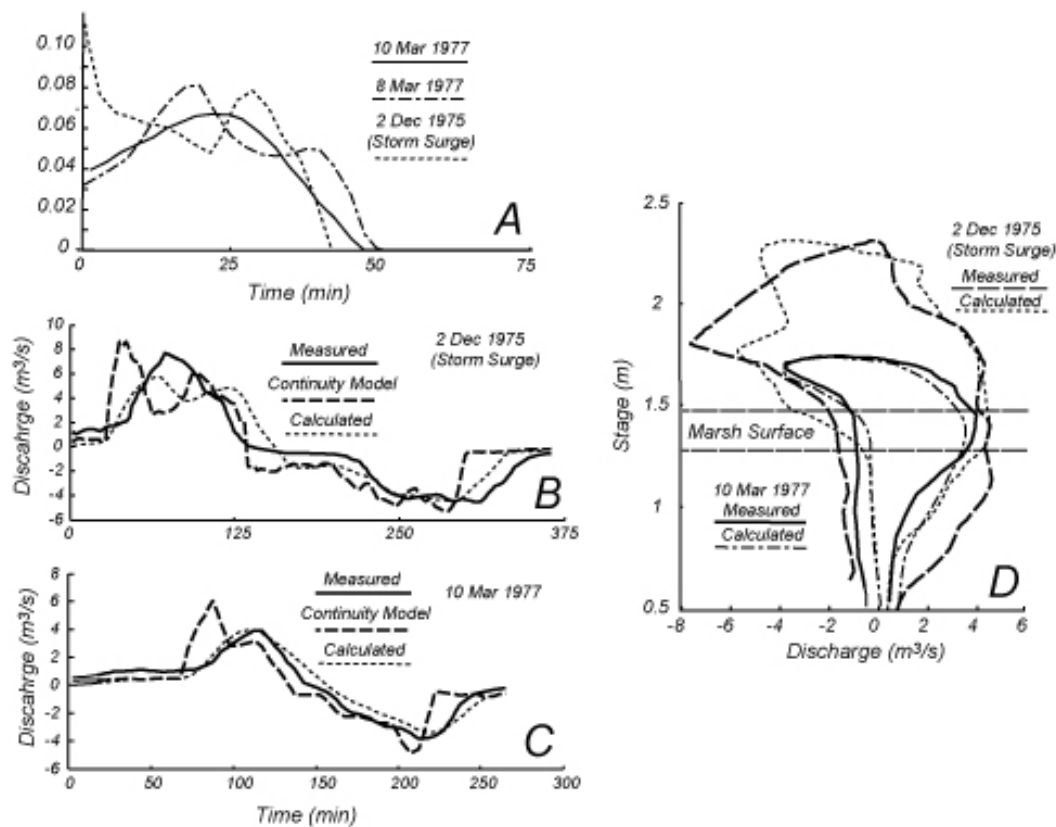


Figure 3. *Determination of the distribution of travel time for the storm surge of Dec. 2 1975 and March 8 1977 in a tidal creek in Warham, UK; a) travel time calculated with a deconvolution of the measured discharge from the continuity model; comparison between measured discharge, discharge obtained from the continuity model, and the geomorphologic unit response model presented herein b) storm surge of Dec. 2 1975; c) spring tide of Mar. 10 1977; d) measured and simulated stage-discharge relationship for the storm surge of Dec. 2 1975 and the spring tide of Mar. 8 1977.*

IMPACT/APPLICATIONS

The possibility of determining the water fluxes from observations of geomorphic features is an appealing approach to the study of tidally-driven flow rates and the structure of tidal channels in muddy coastlines. Our formulation paves the way to the application of recent results on the geomorphic structure of salt marshes and the scaling properties of tidal networks to the determination of marsh creek hydrology.

RELATED PROJECTS

The proposed research is designed to synergistically complement the already funded MURI project “Mechanisms of Fluid Mud Interactions under Waves” (<http://www.ce.jhu.edu/dalrymple/MURI/>). The MURI project studies the interactions between waves and muddy bottomsets in the shelf in front of the Rockefeller State Wildlife Reserve. In this project we will measure the sediment concentration in

nearby tidal channels during the same period, and use this information to tune a model for tidal channel evolution.

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PUBLICATIONS

- Fagherazzi S., Hannion M., D'Odorico P., The Geomorphic Structure of Tidal Hydrodynamics in Salt Marsh Creeks *Water Resources Research* (accepted pending minor revisions)